Simulations of multiple borehole water availability in a semi-arid catchment under different management strategies.

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Context

The Brazilian Northeast (750,000 km², 51 million inhabitants) is a semi-arid region (P = 700 mm yr⁻¹, ETP > 2000 mm yr⁻¹) where the high annual rainfall deficit is accentuated by a short rainy season (3 months) and strong rainfall irregularity. Spatial and temporal heterogeneity of precipitations combined with shallow soils, crystalline basement and high evaporation, lead to interstream flows with a mean duration less than 3 months (Catalá, 1996). In adaptation to this restricted water availability, the inland colonization of the Northeast, which started in the 1650's, has been guided by the river systems that constitute open paths and allow water access to the river bed itself or to the related alluvial aquifer. Indeed, during the dry season, the cattle and human water supply was provided by dug wells (Molle, 1994).

During the last decade, the exploitation of groundwater from the alluvial aquifer of Fiquelima watershed has been favored by the drilling of wells. This allowed the development of irrigated crops, more attractive and lucrative than rain-fed ones. The pressure on water resources is indeed increasing (growing population, increasing domestic needs per capita, irrigation) and it is now an open question whether water availability can be sustained. The main reservoirs in the Fiquelima catchment. Sixty-nine are annual reservoirs, filling and emptying every year; their capacities range from 0.65 hl to 0.3 mm and they are well distributed over the 17 communities (Fig. 1). Four are 1-year reservoirs, with a capacity of about 1 hl, the biggest one is Reservoir Verde (6.7 mm). Salinity is often less than 0.4 g/L; however, this value may increase strongly this value during the dry season (up to 3 g/L). The alluvial aquifer covers about 0.6 km² (23 km by 27 km) by exploitation and the alluviums have a mean depth of 6.8 m. The water table is at about 2.8 m below soil surface at the end of rainy season, the groundwater volume is about 2.3 km³, and the main inflow originates from the interstream river (Bürte et al., 2005).

Objective

To evaluate water availability for different users and different uses within the whole Fiquelima watershed (221 km²) for the next 30 years, according to different possible future evolutions of irrigated crops (the main water consumers).

Methods

1. Characterization of the different water resources (amount, salinity and variability) and development of the related hydrological models (Fig. 2), of the different uses and users, and of the main constraints (physical, socio-political and economic) on water resources management;
2. Development of evolution scenarios for the next 30 years, taking into account the possible increase of the population, and the possible increase of water supply needs per capita, and the need to secure and estimate the required resources on the increase, decrease or stagnation of the irrigated field area and taking into account possible transfer of water from different parts of the watershed to others (release from upstream reservoirs to the river that may feed the downstream aquifer);
3. Simulations, based on a 30-year rainfall series, of the impacts of the above scenarios on the satisfaction or not of the needs of water resources availability and quality in the reservoirs (volume and salinity) and in the aquifer (volume) for main user categories, taking into account a realistic climatic variability.

Results and Discussion

Based on physical and socio-economic issues, three main water territories have been defined ("Aquifer", "Reservoirs" and "Dispersed Habitat"). Considering the next 30 years with a realistic population growth, three hypothesis of irrigated area (i.e., 0.75, 1.50 and 3.50 ha) and several possible water management scenarios, hydrological balance models were built and used to simulate the different impacts on the availability and the salinity of water resources.

- Results from simulations (Table 1) show that, in all cases, releases from the upstream main reservoir are necessary for keeping water salinity at the reservoir below 0.7 g/L and for guaranteeing domestic needs in the whole watershed.
- The simulations show that the area of irrigated fields cannot grow above the present situation (75 ha) without serious problems of availability and salinity of the water resources in the whole watershed. Otherwise, important socio-economic problems, including a high cost of potable water supply with tank reservoirs from external sources, are expected. The consequence is that free extension of irrigated crops, as currently observed, and even encouraged by authorities, is unsustainable.
- To avoid future conflicts, irrigation extension should be restricted through negotiations between communities and irrigating farmers. As a consequence, a management taking into account the interrelations between the three territories appears necessary. A participatory water management, integrating mean related water resources would be hydropowerstasis effective and socially desirable, communities of both "Aquifer" and "Reservoir" territories would benefit from it.

Table 1: Results from simulations for 30 years (population increasing from 3600 to 5680 persons).

<table>
<thead>
<tr>
<th>Conditions of simulations</th>
<th>Surface of irrigated fields</th>
<th>Mean annual consumption for domestic needs (US$/yr)</th>
<th>Time of satisfaction for domestic needs (% of years or months)</th>
<th>Time of satisfaction for the irrigation needs (% of years or months)</th>
<th>Time of satisfaction for ≥ 15% of Reserve Verde (capacity &gt; 0.7 g/L) (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated fields: 0 ha</td>
<td>0.55%</td>
<td>100% years</td>
<td>100% years</td>
<td>100% years</td>
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</tr>
<tr>
<td>50 Ls during 5 months</td>
<td>98%</td>
<td>100% years</td>
<td>100% years</td>
<td>100% years</td>
<td></td>
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<tr>
<td>Irrigated fields: 7.5 ha</td>
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<td>100% years</td>
<td>100% years</td>
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<tr>
<td>50 Ls during 5 months</td>
<td>75%</td>
<td>100% years</td>
<td>100% years</td>
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<td>Irrigated fields: 15.0 ha</td>
<td>85%</td>
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Bibliography


